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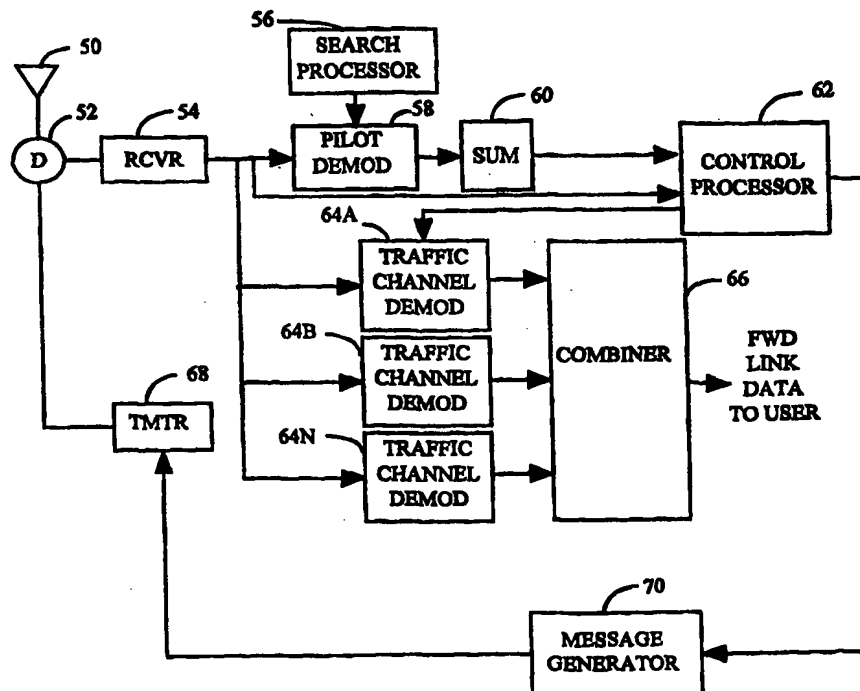
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(54) Title: A METHOD OF AND APPARATUS FOR SELECTING BASE STATIONS TO COMMUNICATE WITH A REMOTE STATION

## (57) Abstract

A mobile station (2), for use in a communication system comprising plural base stations (4) controlled by a base station controller (6), comprises a receiver (50, 52, 54) for receiving signals from plural base stations which together comprise a set of candidate base stations. The mobile station determines power in the received signals, and compares the power with a first threshold value. The mobile station (2) identifies base stations (4) whose signals have a received power greater than the first threshold value and transmits a signal to the controller (6) representing identified base stations as being suitable for inclusion in an active set. The measured pilot energy of each pilot in the candidate set is iteratively compared against a threshold generated in accordance with the sum of the energies of the pilots in the active set. If the strongest pilot in the candidate set satisfies this threshold condition, it is added to the revised active set. A second iterative process is performed to determine whether a pilot should be deleted from the revised active set. The mobile station (2) determines whether a change to the current active set is desirable by measuring the energies of the pilots in the active set and the candidate set, and dynamically adjusting the necessary thresholds based on its own estimation of the communication environment.



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# A METHOD OF AND APPARATUS FOR SELECTING BASE STATIONS TO COMMUNICATE WITH A REMOTE STATION

## BACKGROUND OF THE INVENTION

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### I. Field of the Invention

The present invention relates to a method of and apparatus for selecting base stations to communicate with a remote station. The present invention can be used for performing hand-off in a wireless communication system.

### II. Description of the Related Art

15 The use of code division multiple access (CDMA) modulation techniques is but one of several techniques for facilitating communications in which a large number of system users are present. Although other techniques, such as time division multiple access (TDMA), frequency division multiple access (FDMA) and AM modulation schemes such as  
20 amplitude companded single sideband (ACSSB) are known, CDMA has significant advantages over these other modulation techniques. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR  
25 TERRESTRIAL REPEATERS" and U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", both of which are assigned to the assignee of the present invention and are incorporated by reference. The method for providing CDMA mobile communications was standardized by  
30 the Telecommunications Industry Association in TIA/EIA/IS-95-A entitled "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System".

In the just mentioned patents, a multiple access technique is disclosed in which a large number of mobile telephone users, each having a  
35 transceiver, communicate through satellite repeaters or terrestrial base stations (also known as cell base stations or cell-sites) using code division multiple access (CDMA) spread spectrum communication signals. In using CDMA communications, the frequency spectrum can be reused multiple times thus permitting an increase in system user capacity. The use of CDMA

techniques results in much higher spectral efficiency than can be achieved using other multiple access techniques.

5 A method for simultaneously demodulating data that has traveled along different propagation paths from one base station and for simultaneously demodulating data redundantly provided from more than one base station is disclosed in U.S. Patent No. 5,109,390 (the '390 patent),  
entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR COMMUNICATION SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein. In the '390 patent, the  
10 separately demodulated signals are combined to provide an estimate of the transmitted data which has higher reliability than the data demodulated by any one path or from any one base station.

Handoffs can generally be divided into two categories- hard handoffs and soft handoffs. In a hard handoff, when a mobile station leaves and  
15 origination cell and enters a destination cell, the mobile station breaks its communication link with the origination cell and thereafter establishes a new communication link with the destination cell. In soft handoff, the mobile station completes a communication link with the destination cell prior to breaking its communication link with the origination cell. Thus, in  
20 soft handoff, the mobile station is redundantly in communication with both the origination cell and the destination cell for some period of time.

Soft handoffs are far less likely to drop calls than hard handoffs. In addition, when a mobile station travels near a cell boundary, it may make repeated handoff requests in response to small changes in the environment.  
25 This problem, referred to as ping-ponging, is also greatly lessened by soft handoff. The process for performing soft handoff is described in detail in U.S. Pat. No. 5,101,501, entitled "METHOD AND SYSTEM FOR PROVIDING A SOFT HANDOFF IN COMMUNICATIONS IN A CDMA CELLULAR TELEPHONE SYSTEM" assigned to the assignee of the present invention  
30 and incorporated by reference herein.

An improved soft handoff technique is disclosed in U.S. Pat. No. 5,267,261, entitled "MOBILE STATION ASSISTED SOFT HANDOFF IN A CDMA CELLULAR COMMUNICATIONS SYSTEM", which is assigned to the assignee of the present invention and incorporated by reference herein.  
35 In the system of the '261 patent, the soft handoff process is improved by measuring the strength of "pilot" signals transmitted by each base station within the system at the mobile station. These pilot strength measurements are of assistance in the soft handoff process by facilitating identification of viable base station handoff candidates.

The viable base station candidates can be divided into four sets. The first set, referred to as the Active Set, comprises base stations which are currently in communication with the mobile station. The second set, referred to as the Candidate Set, comprises base stations which have been  
5 determined to be of sufficient strength to be of use to the mobile station. Base stations are added to the candidate set when their measured pilot energy exceeds a predetermined threshold  $T_{ADD}$ . The third set is the set of base stations which are in the vicinity of the mobile station ( and which are not included in the Active Set or the Candidate Set). And the fourth set is  
10 the Remaining Set which consists of all other base stations.

In an IS-95-A communication system, the mobile station sends a Pilot Strength Measurement Message when it finds a pilot of sufficient strength that is not associated with any the of the Forward Traffic Channels currently being demodulated or when the strength of a pilot that is associated with  
15 one of the Forward Traffic Channels being demodulated drops below a threshold for a predetermined period of time. The mobile station sends a Pilot Strength Measurement Message following the detection of a change in the strength of a pilot under the following three conditions:

- 20 1. The strength of a Neighbor Set or Remaining Set pilot is found above the threshold  $T_{ADD}$ .
2. The strength of a Candidate Set pilot exceeds the strength of an Active Set pilot by more that a threshold ( $T_{COMP}$ ).
- 25 3. The strength of a pilot in the Active Set of Candidate Set has fallen below a threshold ( $T_{DROP}$ ) for greater than a predetermined time period.

The Pilot Strength Measurement Message identifies the base station and the  
30 measured pilot energy in decibels.

A negative aspect of soft handoff is that because it involves redundantly transmitting information it consumes the available communication resource. However, soft handoff can provide great improvement in the quality of communication. Therefore, there is a need  
35 felt in the art for a method of minimizing the number of base stations transmitting redundant data to a mobile station user which provides sufficient transmission quality.

## SUMMARY OF THE INVENTION

According to one aspect of the invention there is provided a method for selecting base stations to communicate with a remote station comprising: measuring, in said remote station, a combination of signal energies over a predetermined time period from base stations capable of communicating with said remote station; computing, in said remote station, a first threshold value in response said measurement; comparing, in said remote station, a signal energy of a first base station with said first threshold; and selecting, in said remote station, said first base station when said signal energy of said first base station exceeds said first threshold.

According to another aspect of the invention there is provided a mobile station for use in a communication system comprising plural base stations controlled by a base station controller, the mobile station comprising: a receiver for receiving signals from plural base stations which together comprise a set of candidate base stations; means for determining power in the received signals; first means for comparing the power in the received signal with a first threshold value; means for identifying base stations whose signals have a received power greater than the first threshold value; and means for transmitting a signal to the controller representing identified base stations as being suitable for inclusion in an active set.

The present invention is embodied in a novel and improved method and apparatus for providing soft handoff in a mobile communication system. It should be noted at the outset, that one of the biggest problems with current systems is that the members of active set are determined in accordance with comparisons of measured pilot energy with fixed thresholds. However, the value of providing a redundant communication link to a mobile station depends strongly on the energy of other signals being provided to the mobile station. For example, the value of redundantly transmitting to a mobile station a signal with received energy corresponding to a pilot strength of -15 dB will not be of much value, if the mobile station is already receiving a transmission with signal energy corresponding to a pilot strength of -5dB. However, redundantly transmitting to a mobile station a signal of received energy corresponding to a pilot strength of -15 dB may be of substantial value, if the mobile station is receiving transmissions with signal energy corresponding to a pilot energy of only -13dB.

At the mobile station, in determining whether to send a message indicating that a pilot from the candidate set should be moved to a revised active set, the measured pilot energy of each pilot in the candidate set is

iteratively compared against a threshold generated in accordance with the a variable COMBINED\_PILOT which is the sum of the energies (i.e. the  $E_c/I_o$ ) of the pilots in the active set. In the preferred embodiment, the optimum value of this threshold is determined by the mobile station itself, without  
5 the need to send these thresholds over the air or to verify the mobile station requests at the base station. If the strongest pilot in the candidate set satisfies this threshold condition, it is added to the revised active set, and COMBINED\_PILOT is recomputed to include the newly added pilot signal.

Following the iterative process performed on the members of the  
10 candidate set, a second iterative process is performed to determine whether a pilot should be deleted from the revised active set. In this operation, pilots are tested from the weakest member of revised active set to the strongest. A COMBINED\_PILOT energy value is computed that is the sum of the energies of all pilots belonging to the active set. A threshold value is  
15 generated in accordance with the COMBINED\_PILOT value as described above and the pilot signal being tested is compared with the threshold. Again, this threshold is determined at the mobile station in order to avoid excessive signaling. If a pilot has been below the threshold value for a predetermined period of time, a message would be sent to the base station  
20 indicating that such a pilot should be dropped.

The revised active set list is transmitted to the base station controller through the base stations with which the mobile station is in communication. The base station controller sets up the communication links with the base stations in the mobile generated revised active set list  
25 and generates an acknowledgment for the mobile station when the links are set up. The mobile station then conducts communications through the base stations of the revised active set.

In the preferred embodiment, the mobile station monitors the pilot signals and in response to the monitored pilot signals the mobile station  
30 compiles members of the candidate set. Moreover, the mobile station determines whether a change to the current active set is desirable in view of the criteria discussed above by measuring the energies of the pilots in the active set and the candidate set, and dynamically adjusting the necessary thresholds based on its own estimation of the communication  
35 environment. Upon determining any change in the desired membership of the active set, the mobile station generates a pilot strength measurement message that as described above includes the identities of all pilots in the candidate and active sets, their corresponding measured energy values, and

a corresponding indication whether the pilot should remain in the sets or be moved into the neighbor set.

## BRIEF DESCRIPTION OF THE DRAWINGS

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The features, objects, and advantages of the present invention will become more apparent from the detailed description of an embodiment of the invention set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and

10 wherein:

FIG. 1 is an illustration of a cellular communication network;

FIG. 2 is an illustration of the cellular communication network of FIG. and includes a base station controller;

FIG. 3 is a block diagram of a mobile station embodying the present

15 invention;

FIG. 4 is a block diagram of a base station embodying the present invention;

FIG. 5 is a graph of dynamic thresholds versus combined energies of pilots in an active set, illustrating the linear operations performed on soft handoff parameters;

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FIG. 6 is a flow diagram of a method for generating a revised active set in the mobile station; and

FIG. 7 is state diagram illustrating the operation of the present invention.

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## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates wireless communication network in which the geographical area has been divided up into coverage areas referred to as cells and illustrated by a set of adjacent hexagons. Each cell is served by a corresponding base station 4. Each base station 4 transmits a pilot signal which uniquely identifies that base station. In the exemplary embodiment, the base stations 4 are CDMA base stations. A detail description of soft hand-off in a wireless CDMA communication system is described in detail in the

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aforementioned U.S. Patent Nos. 5,101,501 and 5,267,261.

Mobile station 2 is located within the cell served by base station 4A. Since mobile station 2 is located near the cell boundary, it will likely be in a soft hand-off condition, in which it is simultaneously in communication



with more than one base station. It may, for example be in communication with base stations 4A and 4B. Thus, base stations 4A and 4B are said to make up the active set. Moreover, it may be that mobile station 2 has determined other base stations in its vicinity to have a measured pilot energy above a predetermined threshold  $T_{ADD}$ , but that those base stations are not currently in communication with the mobile station. Those pilots are said to make up the candidate set. The candidate set could be made up of base stations 4C and 4G.

Referring to FIG. 2, a typical communication network is illustrated. Data directed to mobile station 2 is provided from a public switched telephone network or other wireless system (not shown) to base station controller 6. Base station controller 6 provides the data to the base stations in mobile station 2's active list. In the example, base station controller 6 redundantly provides data to and receives data from base stations 4A and 4B.

The present invention is equally applicable to conditions where each cell is divided into sectors. Communications to and from each sector can be separately received and demodulated by mobile station 2. For simplicity, the discussion will be described wherein in each base of base station 4 are uniquely located base stations. However, it will be readily seen by one skilled in the art that the present invention is equally applicable to sectored cells, simply by considering the possibility that the base stations can be collocated and transmitting to separate sectors within a cell. The condition where a mobile station is in simultaneous communication with more than one sector of a cell is referred to as softer handoff. The method and apparatus for performing softer hand-off are described in detail in copending U.S. Patent Application No. 08/144,903, entitled "METHOD AND APPARATUS FOR PERFORMING HANDOFF BETWEEN SECTORS OF A COMMON BASE STATION", filed October 30, 1993, which is assigned to the assignee of the present invention and incorporated by reference herein.

Within mobile station 2, each copy of the data packet is separately received, demodulated and decoded. The decoded data is then combined to give a estimate of the data of greater reliability than any one of demodulated estimates of the data.

FIG. 3 illustrates a mobile station 2 in greater detail. Mobile station 2 continuously or at intermittent intervals measures the strength of pilot signals of base stations 4. Signals received by antenna 50 of mobile station 2 are provided through duplexer 52 to receiver (RCVR) 54 which amplifies, downconverts, and filters the received signal and provides it to pilot demodulator 58 of searcher subsystem 55.

In addition, the received signal is provided to traffic demodulators 64A-64N. Traffic demodulators 64A-64N, or a subset thereof, separately demodulate signals received by mobile station 2. The demodulated signals from traffic demodulators 64A-64N are provided to combiner 66 which  
5 combines the demodulated data, which in turn provides an improved estimate of the transmitted data.

Mobile station 2 measures the strength of pilot channels. Control processor 62 provides acquisition parameters to search processor 56. In the exemplary embodiment of a CDMA communication system, control  
10 processor 62 provides a PN offset to search processor 56. Search processor 56 generates a PN sequence which is used by pilot demodulator 58 to demodulate the received signal. The demodulated pilot signal is provided to energy accumulator 60 which measures the energy of the demodulated pilot signal, by accumulating the energy for predetermined lengths of time.

15 The measured pilot energy values are provided to control processor 62. In the exemplary embodiment, control processor 62 compares the energy values to thresholds  $T_{ADD}$  and  $T_{DROP}$ .  $T_{ADD}$  is threshold above which the received signal is of sufficient strength to effectively provide communications with mobile station 2.  $T_{DROP}$  is a threshold value below  
20 which the received signal energy is insufficient to effectively provide communications with mobile station 2.

Mobile station 2 transmits a Pilot Strength Measurement Message which includes all pilots with energy greater than  $T_{ADD}$  and all members of the current active set who's measured pilot energy has not fallen below  
25  $T_{DROP}$  for more than a predetermined time period. In the exemplary embodiment, mobile station 2 generates and transmits a Pilot Strength Measurement Message following the detection of a change in the strength of a pilot under the following three conditions:

- 30 1. The strength of a Neighbor Set or Remaining Set pilot is found above the threshold ( $T_{ADD}$ ).
2. The strength of a Candidate Set pilot exceeds the strength of an Active Set pilot by more than a threshold ( $T_{COMP}$ ).
- 35 3. The strength of a pilot in the Active Set has fallen below a threshold ( $T_{DROP}$ ) for greater than a predetermined time period.

In the exemplary embodiment, the Pilot Strength Measurement Message  
40 identifies the pilot and provides a corresponding measured pilot energy. In

the exemplary embodiment, the base stations in the Pilot Strength Measurement Message are identified by their pilot offsets and their corresponding measured pilot energy is provided in units of decibels. The values of  $T_{ADD}$  and  $T_{DROP}$  may be pre-programmed into the mobile station 2 or provided to the mobile station 2 by the base station 4 (see FIG. 4). Furthermore, they may be calculated by the mobile station 2 itself.

Control processor 62 provides the identities of the pilots and their corresponding measured pilot energies to message generator 70. Message generator 70 generates a Pilot Strength Measurement Message containing the information. The Pilot Strength Measurement Message is provided to transmitter (TMTR) 68, which encodes, modulates, upconverts and amplifies the message. The message is then transmitted through duplexer 52 and antenna 50.

Referring to FIG. 4, the Pilot Strength Measurement Message is received by antenna 30 of base station 4 and provided to receiver (RCVR) 28, which amplifies, down converts, demodulates and decodes the received signal and provides the message to base station controller (BSC) interface 26. Base station controller (BSC) interface 26 sends the message to base station controller (BSC) 6. The message is provided to selector 22, which may also receive the message redundantly from other base stations which are in communication with mobile station 2. Selector 22 combines message estimates received from the base stations in communication with mobile station 2 to provide improved packet estimates.

Preferably, the mobile station 2 monitors the pilot signals and compiles members of each of the above-mentioned sets (active, candidate, and neighbor). Additionally, the mobile station 2 preferably determines whether a change to the current active set is desirable according to the following linear relationships:

$$Y1 = \text{SOFT\_SLOPE} * \text{COMBINED\_PILOT} + \text{ADD\_INTERCEPT} \quad (1)$$

$$Y2 = \text{SOFT\_SLOPE} * \text{COMBINED\_PILOT} + \text{DROP\_INTERCEPT} \quad (2)$$

where  $Y1$  is the dynamic threshold above which a candidate set pilot's measured energy must rise before the mobile station will request adding it to the revised active set, and  $Y2$  is the dynamic threshold below which an active set pilot's energy must fall before the mobile station will request moving it from the active set to the candidate set. To provide hysteresis,  $Y1$  is preferably greater than  $Y2$ .

From Equations (1) and (2), it can be seen that if a particular active set pilot's measured energy falls below Y2, it is moved to the candidate set. In order for that same pilot to be added back into the revised active set, one of two things must happen; either the value of COMBINED\_PILOT decreases  
 5 by some amount  $\Delta_1$ , or that pilot's own measured energy increases by some amount  $\Delta_2$ . Thus, it can be seen that  $\Delta_1$  and  $\Delta_2$  are the hysteresis values of the COMBINED\_PILOT and individual pilot energy respectively needed to prevent a given pilot from being repeatedly moving in and out of the active set.

10 Thus, pilots should be added to the revised active set when the COMBINED\_PILOT value is less than or equal to  $X_1$ , and should be dropped from the active set when the COMBINED\_PILOT value is greater than or equal to  $X_2$ . From Equations (1) and (2), it can be shown that:

$$15 \quad \text{SOFT\_SLOPE} = \Delta_2 / \Delta_1; \quad (3)$$

$$\text{DROP\_INTERCEPT} = T_{\text{DROP}} - X_2 * \Delta_2 / \Delta_1; \text{ and} \quad (4)$$

$$20 \quad \text{ADD\_INTERCEPT} = \text{DROP\_INTERCEPT} + \Delta_2. \quad (5)$$

This relationship is further illustrated in FIG. 5. The dynamic thresholds Y1 and Y2 are plotted in dB as a function of combined pilot energy (i.e.  $E_c/I_0$ ), also in dB. As can be seen, they are both linear functions with a slope of SOFT\_SLOPE (i.e.  $\Delta_2/\Delta_1$  from Equation (3)), and respective y-  
 25 intercepts of ADD\_INTERCEPT and DROP\_INTERCEPT. Note that the y-intercept values may be negative, and DROP\_INTERCEPT is illustrated in FIG. 5 as a negative value.

An exemplary value for SOFT\_SLOPE is 2. In the preferred embodiment, the mobile station 2 itself may calculate the value of  
 30 SOFT\_SLOPE by estimating the desired values for  $\Delta_1$  and  $\Delta_2$  by monitoring the fluctuation of all pilots in both the active and candidate sets as described above with reference to FIG. 3, and then applying the relationship of Equation (3). The mobile station 2, and specifically control processor 62, may estimate the value of  $\Delta_1$  by measuring the variations in COMBINED\_PILOT  
 35 over a predetermined amount of time. For example,  $\Delta_1$  in the preferred embodiment is equal to the standard deviation of the COMBINED\_PILOT over a predetermined period to prevent natural variations in COMBINED\_PILOT from causing a handoff request. Additionally,  $\Delta_2$  in the preferred embodiment may be set equal to the difference between  $T_{\text{ADD}}$  and

$T_{DROP}$  because the difference between  $T_{ADD}$  and  $T_{DROP}$  is the same order of hysteresis required for  $\Delta_2$ .

As previously discussed,  $X_1$  is shown as the value of COMBINED\_PILOT which is sufficient to cause a pilot to be added to the revised active set (i.e. where  $Y_1$  intersects  $T_{ADD}$ ). Also,  $X_2$  is shown as the value of COMBINED\_PILOT which is sufficient to cause a pilot to be dropped from the active set (i.e. where  $Y_2$  intersects  $T_{DROP}$ ). The value of  $X_2$  may be pre-programmed into the mobile station, or provided to the mobile station in a signaling message from the base station. In the preferred embodiment, it is a value high enough to provide a sufficiently robust forward link, while at the same time avoiding unnecessary redundancy. An exemplary value for  $X_2$  is -7.11 dB. In the preferred embodiment, the mobile station itself may determine the value  $X_1$  from its calculation of  $\Delta_1$ ,  $\Delta_2$  and the known values of  $X_2$  and  $T_{DROP}$ . Thus, if  $\Delta_1=1.5$ ,  $\Delta_2=3$ ,  $X_2=-7.11$  dB, and  $T_{DROP}=12.44$  dB; then  $SOFT\_SLOPE = 2$ ,  $ADD\_INTERCEPT=1.22$  dB,  $DROP\_INTERCEPT=-1.78$  dB and  $X_1=-7.61$  dB by Equations (1)-(5) above.

The handoff parameters illustrated above are generated at mobile station 2. These handoff parameters are used as described below to generate a revised active set. By generating the handoff parameters at mobile station 2, rather than at base station 4 or base station controller 6, they may be generated much more quickly and without excessive signaling. Additionally, this avoids having to perform any verification calculation at the base station 4 or base station controller 6. Mobile station 2 measures received pilot energy as described above with respect to FIG. 3. The pilot energy values are provided to control processor 62. In response, control processor 62 generates the handoff parameters. If, based on the handoff parameters generated by the mobile station, a pilot is required to be added to or dropped from the current active set, mobile station 2 transmits a message indicating the members of the revised active set to base station controller 6 through base stations 4. Base station controller 6 sets up communications with mobile station 2. Mobile station 2 reconfigures traffic channel demodulators 64A-64N to demodulate received signals in accordance with the mobile generated revised active set.

In the exemplary embodiment, control processor 62 in mobile station 2 generates the revised active set in accordance with the method shown in FIG. 6. In block 200, pilots with measured energy in excess of threshold  $T_{ADD}$  are added to the candidate list, whereas pilots whose measured energy has fallen below  $T_{DROP}$  for more than a predetermined time period are removed from the candidate list. In the exemplary embodiment, the time a pilot is

below  $T_{\text{DROP}}$  is tracked by a timer within control processor 62 referred to herein as the  $T_{\text{DROP}}$  timer. The  $T_{\text{DROP}}$  timer is a timer that keeps track of the time that a pilot has been below the drop threshold. The purpose of the  $T_{\text{DROP}}$  timer is to avoid mistakenly dropping a strong pilot which may have a weak measured energy due to short duration change in the propagation environment, such as a fast fade.

In block 202, the pilots in the candidate list are sorted from strongest to weakest. Thus,  $P_{C1}$  is stronger than  $P_{C2}$ , and so on, where  $P_{Ci}$  is preferably the  $E_C/I_0$  for the candidate pilot  $i$  as defined in paragraph 6.6.6.2.2 of EIA/TIA IS-95A. In block 204, the variable COMBINED\_PILOT is set equal to the energy of all pilots in the active set. Also, in block 204, loop variable (i) is initialized to the value 1. In block 206, the candidate set member  $P_{Ci}$  is tested to determine whether it should be made part of the revised active set.  $P_{Ci}$  is compared against a threshold generated in accordance with the current value of COMBINED\_PILOT. In the exemplary embodiment, the threshold (Y1) is generated in accordance with equation (1) above.

If the pilot energy of  $P_{Ci}$  exceeds threshold Y1, then the flow moves to block 208. In block 208, a Pilot Strength Measurement Message (PSMM) is sent from mobile station 2 to base station 4 requesting that pilot  $P_{Ci}$  be added to the active set. The base station 4 then sends a response message directing mobile station 2 to add pilot  $P_{Ci}$  to the active set. In block 210, a new value of COMBINED\_PILOT is computed which is equal to the old value of COMBINED\_PILOT plus the energy of pilot  $P_{Ci}$ . In block 212, the loop variable (i) is incremented.

In block 213, it is determined whether all pilots in the candidate set have been tested. If all pilots in the candidate set have not been tested, then the flow moves to block 200 and proceeds as described above. If all pilots in the candidate set have been tested or if, back in block 206, the pilot energy of  $P_{Ci}$  did not exceed threshold Y1, then the flow moves to block 214. In block 214, the revised active set is sorted from lowest energy to highest energy. Thus,  $P_{A1}$  has the minimum measured energy in the revised active set,  $P_{A2}$  has the second lowest and so on up to the last member of the revised active set  $P_{AN}$ .

In block 218, loop variable  $i$  is set to 1. In block 220, COMBINED\_PILOT for testing  $P_{Ai}$  is computed. The value of COMBINED\_PILOT is set equal to the sum of the measured energy of all pilots currently in the active set and having energy greater than the pilot currently being tested. Thus, COMBINED\_PILOT is determined by the equation:

$$\text{COMBINED\_PILOT} = \sum_{j=i+1}^N P_{A_j} \quad \text{in dB} \quad (6)$$

where N is the number of pilots in the active set.

In block 222, the current pilot being tested is compared against a threshold (Y2) determined in accordance with the computed value of COMBINED\_PILOT. In the exemplary embodiment, threshold Y2 is determined in accordance with equation (2) above. If the measured pilot energy  $P_{A_i}$  exceeds threshold Y2, then the flow moves to block 224 and the  $T_{\text{TDROP}}$  drop timers for pilots  $P_{A_i}$  to  $P_{A_N}$  are reset to zero and determination of the revised active set ends in block 234.

If the measured pilot energy  $P_{A_i}$  does not exceed threshold Y2, then the flow moves to block 226. In block 226, it is determined whether the  $T_{\text{TDROP}}$  timer for  $P_{A_i}$  has expired. If the  $T_{\text{TDROP}}$  timer has expired, then, in block 228, the mobile station 2 sends a PSMM to base station 4 requesting that pilot  $P_{A_i}$  be removed from the active set and put in the candidate set. Base station 4 sends an affirmative response message, and the flow proceeds to block 230. If in block 226, it is determined that the  $T_{\text{TDROP}}$  timer for  $P_{A_i}$  has not expired, then the flow proceeds directly to block 230. In block 230, the loop variable (i) is incremented. Then, in block 232, it is determined whether all the pilots in the active set  $P_{A_i}$  have been tested. If all the pilots in the active set have been tested, then the flow proceeds to block 234 and generation of the revised active set is complete. If all the pilots in the active set have not been tested, then the flow proceeds to block 220 and proceeds as described above.

FIG. 7 shows a state diagram of the operation of the present invention. A given pilot,  $P_{N_i}$ , may begin in the neighbor set 700. If the  $E_c/I_0$  of the pilot  $P_{N_i}$  exceeds the threshold  $T_{\text{ADD}}$ , then it is added to the Candidate Set 702 by mobile station 2. If a pilot,  $P_{c_i}$ , is in the candidate set 702, and its  $E_c/I_0$  falls below the threshold  $T_{\text{DROP}}$  and its  $T_{\text{TDROP}}$  timer expires, then it is moved by mobile station 2 from the candidate set 702 to the neighbor set 700. These two transitions just described correspond to block 200 of FIG. 6 - adding and removing pilots from the candidate set.

If the  $E_c/I_0$  of a pilot,  $P_{c_i}$ , in the candidate set exceeds the dynamic threshold Y1 as determined in accordance with Equation (1) above, then a PSMM 706 is sent by mobile station 2 to base station 4 requesting that  $P_{c_i}$  be added to the active set 708. In response, the base station 4 sends an Extended Handoff Direction Message (EHDM), directing mobile station 2 to add  $P_{c_i}$  to

the active set 708. These two transitions just described correspond to blocks 202-213 of FIG. 6.

5 If the  $E_C/I_0$  of a pilot  $P_{ai}$  in the active set is less than the dynamic threshold  $Y_2$ , and its  $T_{TDROP}$  timer expires, the mobile station 2 sends a PSMM 710 to base station 4 requesting that pilot  $P_{ai}$  be dropped from the active set. In response, base station 4 sends an EHDM, directing mobile station 2 to drop  $P_{ai}$  from the active set to the candidate set 702. These two transitions just described correspond to blocks 214-228 of FIG. 6.

10 If the  $E_C/I_0$  of a pilot  $P_{ai}$  in the active set is less than the threshold  $T_{DROP}$  and its  $T_{TDROP}$  timer expires, the mobile station 2 sends a PSMM 704 to base station 4 requesting that pilot  $P_{ai}$  be dropped from the active set. In response, base station 4 sends an EHDM, directing mobile station 2 to drop  $P_{ai}$  from the active set to the neighbor set 702. There is no corresponding flow diagram herein for these two transitions.

15 The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty.  
20 Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

**I CLAIM:**



## CLAIMS

1. A method for selecting base stations to communicate with a  
2 remote station comprising:  
measuring, in said remote station, a combination of signal energies  
4 over a predetermined time period from base stations capable of  
communicating with said remote station;  
6 computing, in said remote station, a first threshold value in response  
said measurement;  
8 comparing, in said remote station, a signal energy of a first base  
station with said first threshold; and  
10 selecting, in said remote station, said first base station when said  
signal energy of said first base station exceeds said first threshold.

2. The method of Claim 1 wherein said signal energy of said first  
2 base station is the energy of a first base station pilot signal measured at said  
remote station.

3. The method of Claim 2 wherein said combination of signal  
2 energies from base stations capable of communicating with said remote  
station comprises the sum of pilot energy values of pilot signals with greater  
4 received energy than said first base station.

4. The method of Claim 3 wherein said step of computing a  
2 threshold value comprises performing a linear operation upon said  
combination of signal energies from base stations capable of communicating  
4 with said remote station.

5. The method of Claim 4 wherein a slope of said linear operation  
2 is calculated in said remote station in response to a variation in said  
combination of signal energies over a predetermined time period.

6. The method of Claim 5 wherein an intercept of said linear  
2 operation is calculated in said remote station in response to stored system  
parameters.

7. The method of Claim 6 wherein said linear operation  
2 comprises:

- 4 multiplying said combination of signal energies from base stations  
4 capable of communicating with said remote station by a first variable; and  
summing a second variable with the product of said multiplication.

8. The method of Claim 7 further comprising the step of  
2 transmitting a message indicative of said measured pilot signals from said  
remote station.

9. A mobile station for use in a communication system  
2 comprising plural base stations controlled by a base station controller, the  
mobile station comprising:  
4 a receiver for receiving signals from plural base stations which  
together comprise a set of candidate base stations;  
6 means for determining power in the received signals;  
first means for comparing the power in the received signal with a first  
8 threshold value;  
means for identifying base stations whose signals have a received  
10 power greater than the first threshold value; and  
means for transmitting a signal to the controller representing  
12 identified base stations as being suitable for inclusion in an active set.

10. A mobile station as claimed in claim 9, wherein said means for  
2 determining power comprises means for accumulating energy values for the  
received signals for a predetermined period of time.

11. A mobile station as claimed in claim 9 or 10, wherein said first  
2 means for comparing comprises means for calculating the first threshold  
dynamically.

12. A mobile station as claimed in claim 11, further comprising  
2 means for receiving one or more of the predetermined parameters in a  
signal transmitted from a base station.

13. A mobile station as claimed in claim 11, further comprising  
2 means for storing a preprogrammed one or more of the predetermined  
parameters.

14. A mobile station as claimed in any of claims 9 to 13, further  
2 comprising:

- second means for comparing the power in the received signals of base  
4 stations in the active set with a second threshold value;  
means for identifying base stations in the active set whose signals  
6 have a received power less than the second threshold value for a  
predetermined period of time; and  
8 means for transmitting a signal to the controller representing  
identified base stations as being suitable for removal from the active set.

15. A mobile station as claimed in claim 14, wherein said second  
2 means for comparing comprises means for calculating the second threshold  
dynamically.

16. A mobile station as claimed in claim 15, further comprising  
2 means for receiving one or more of the predetermined parameters in a  
signal transmitted from a base station.

17. A mobile station as claimed in claim 16, further comprising  
2 means for storing a preprogrammed one or more of the predetermined  
parameters.

18. A mobile station as claimed in any of claims 14 to 17, wherein  
2 base stations identified as being suitable for removal from the active set are  
transferred to a set of neighboring base stations.

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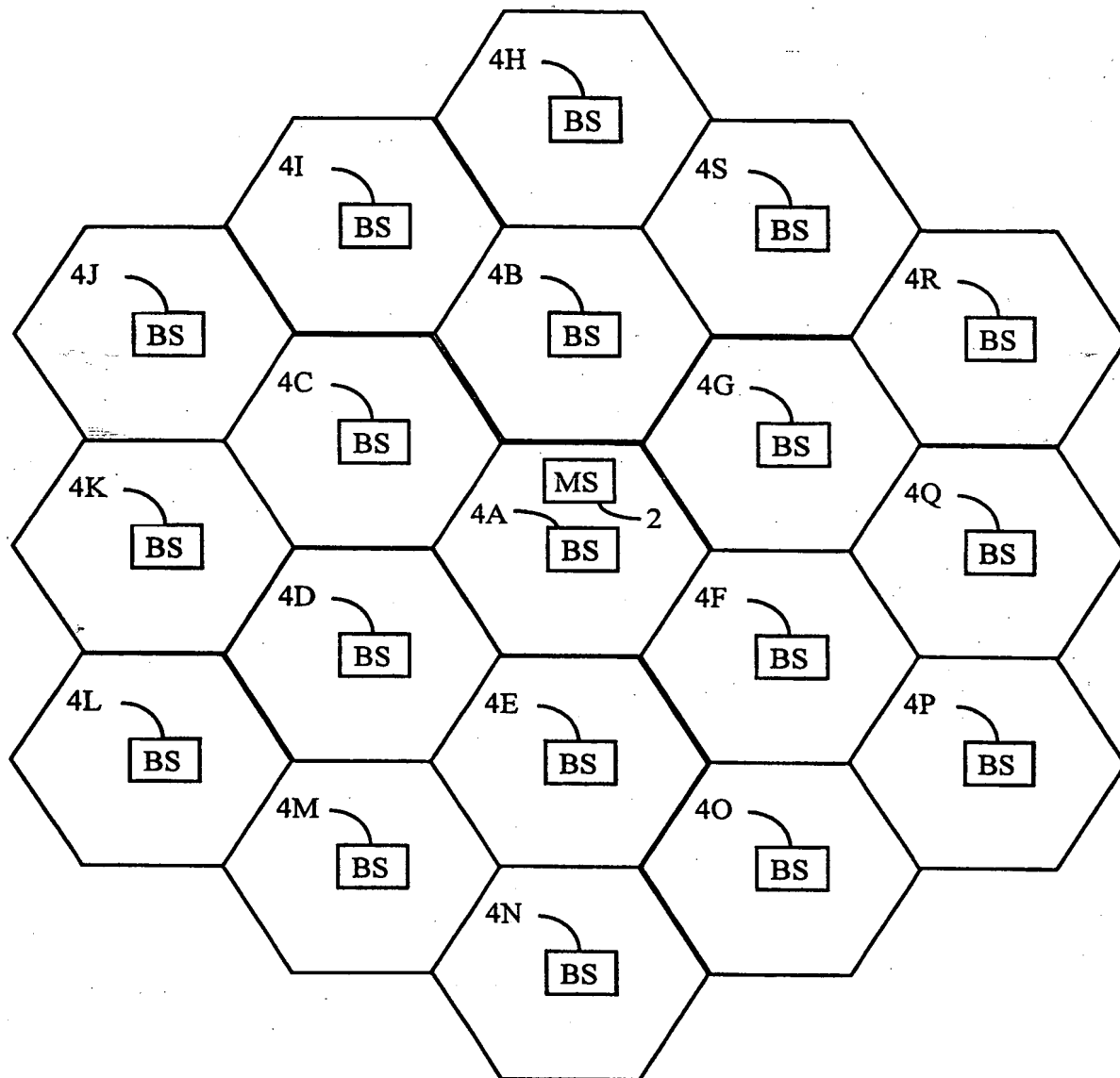
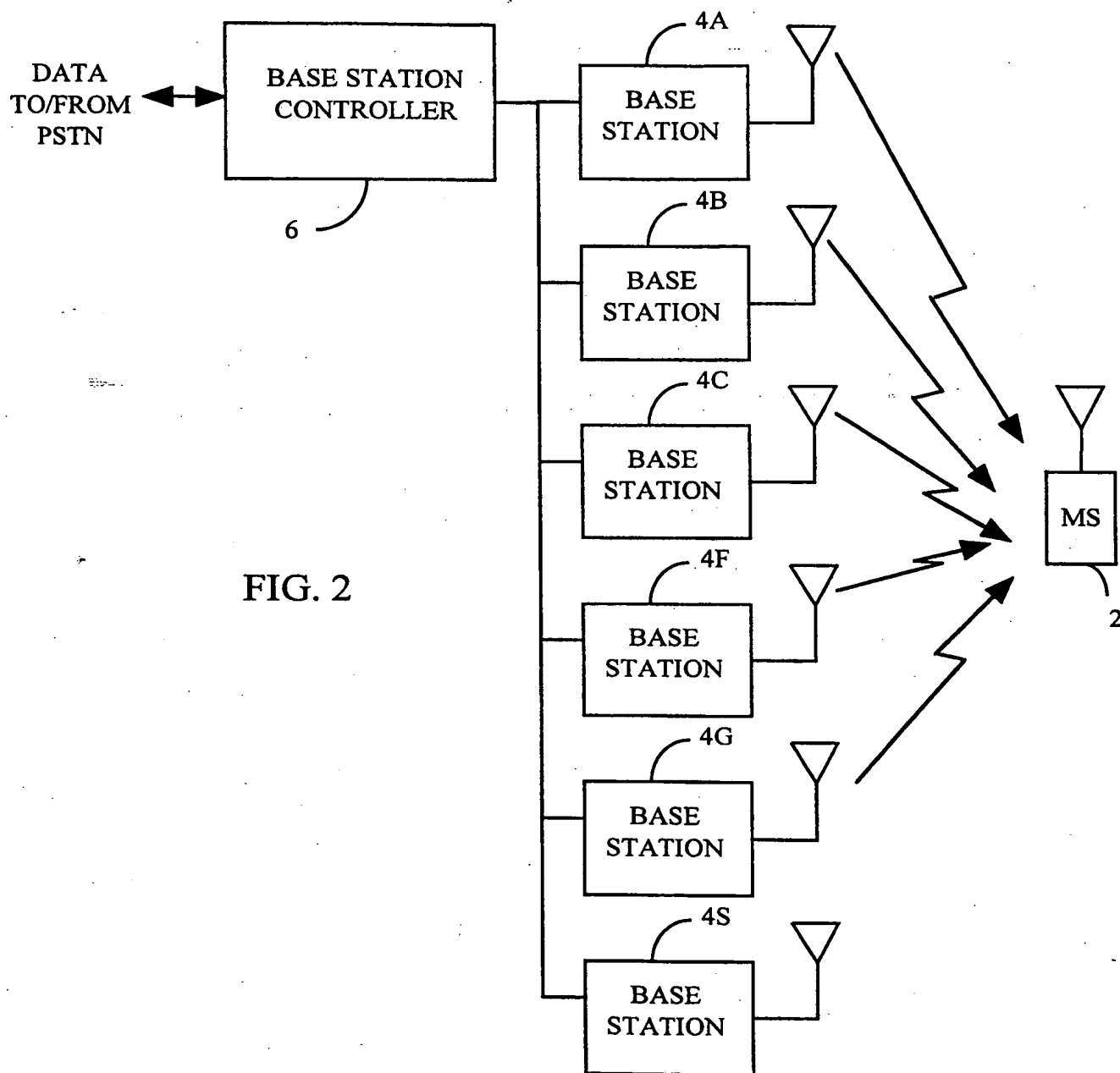


FIG. 1

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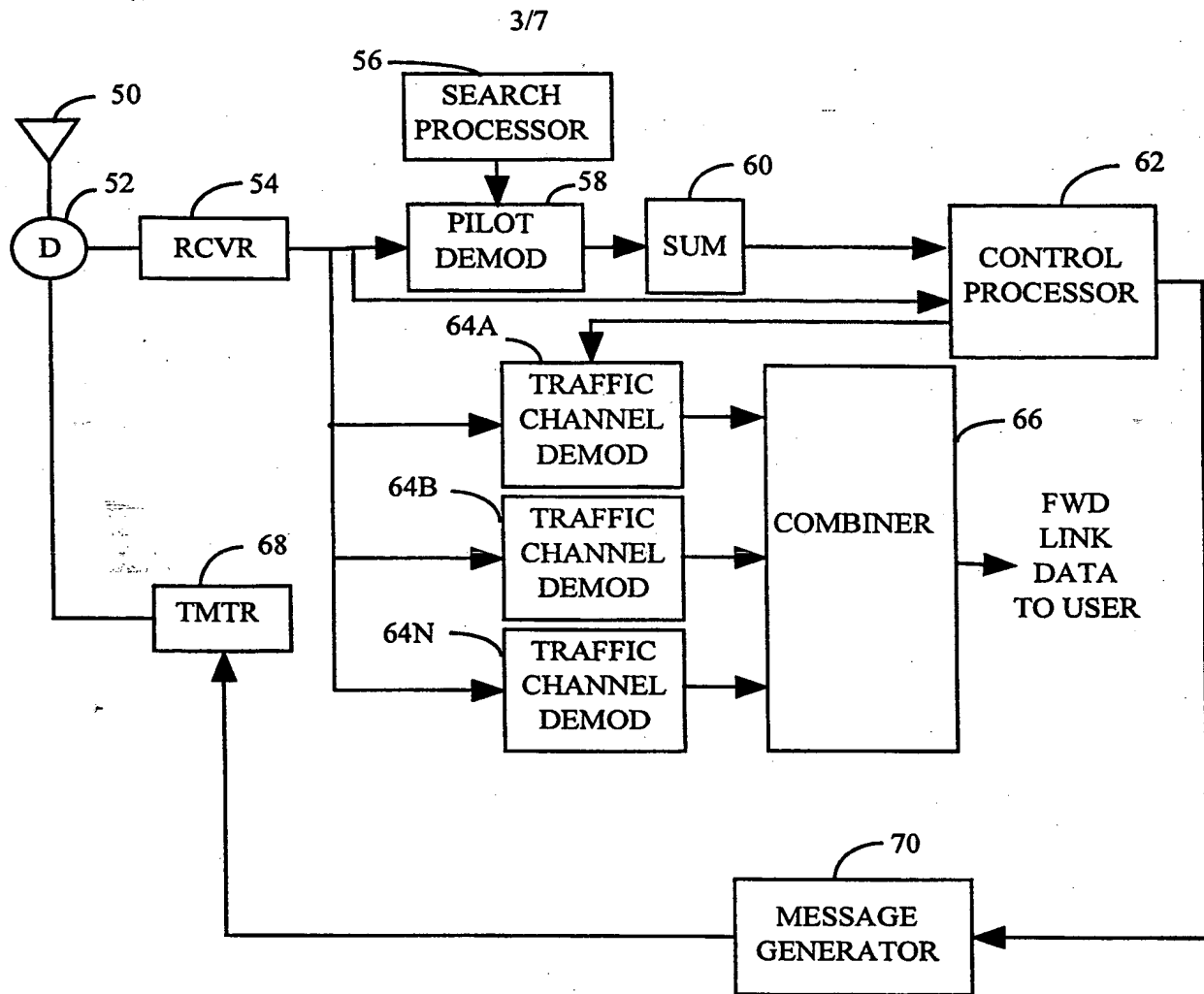


FIG. 3

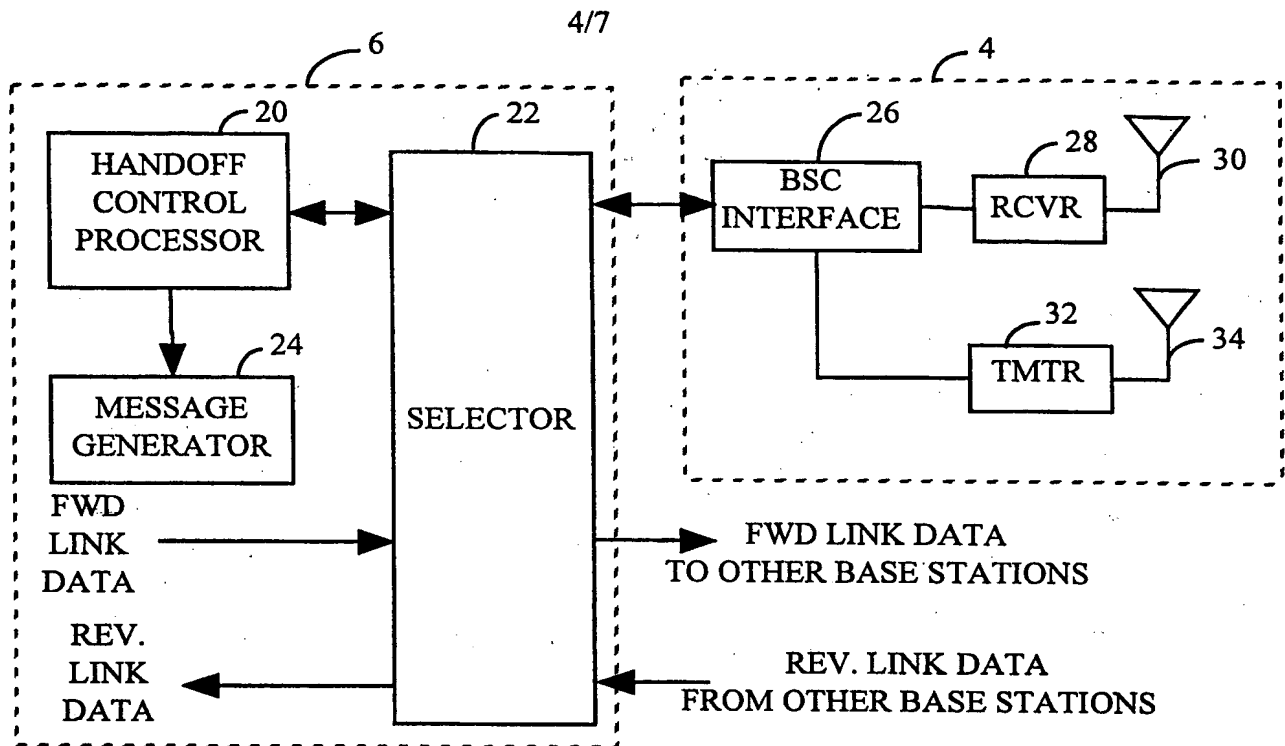


FIG. 4

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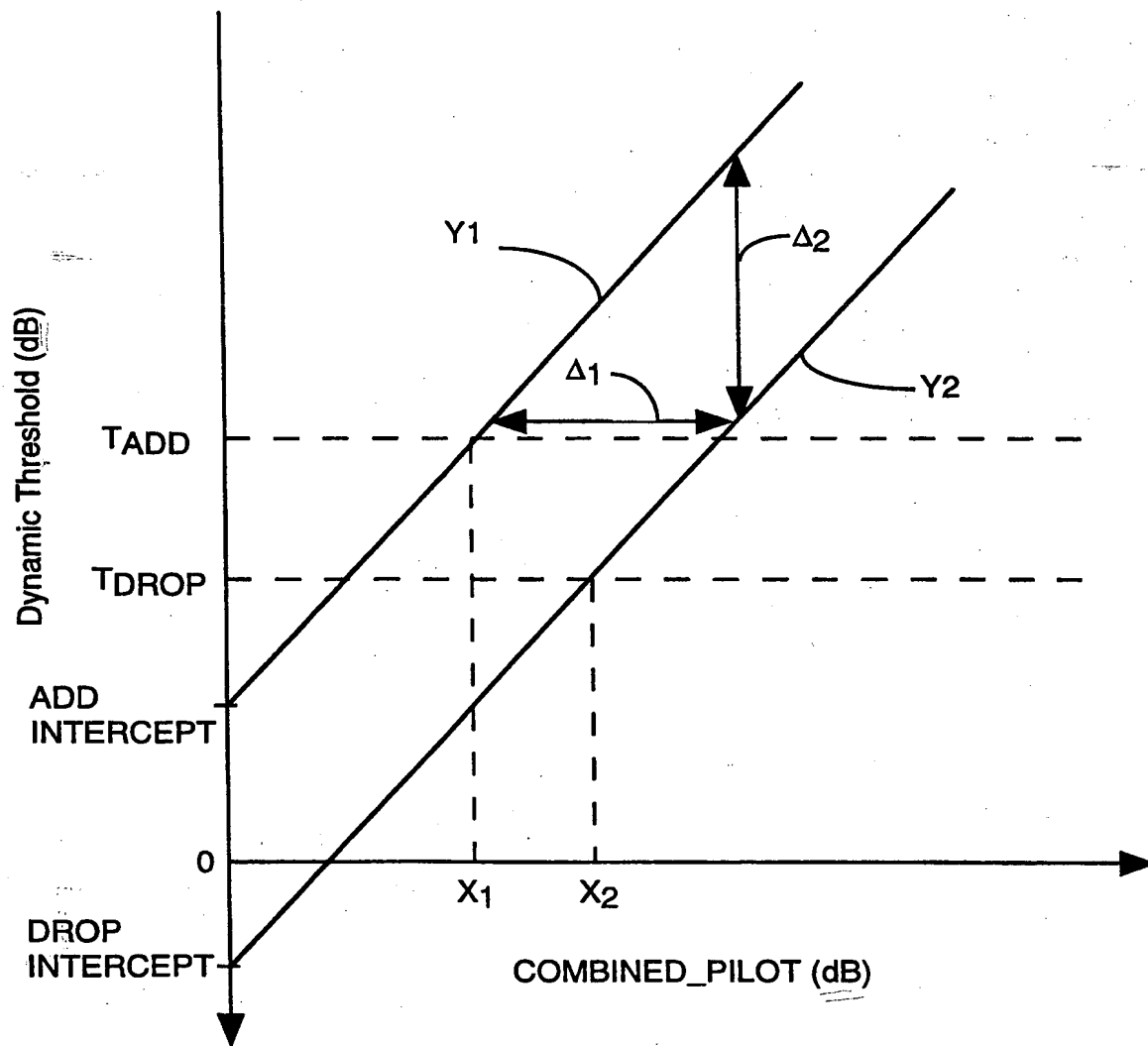
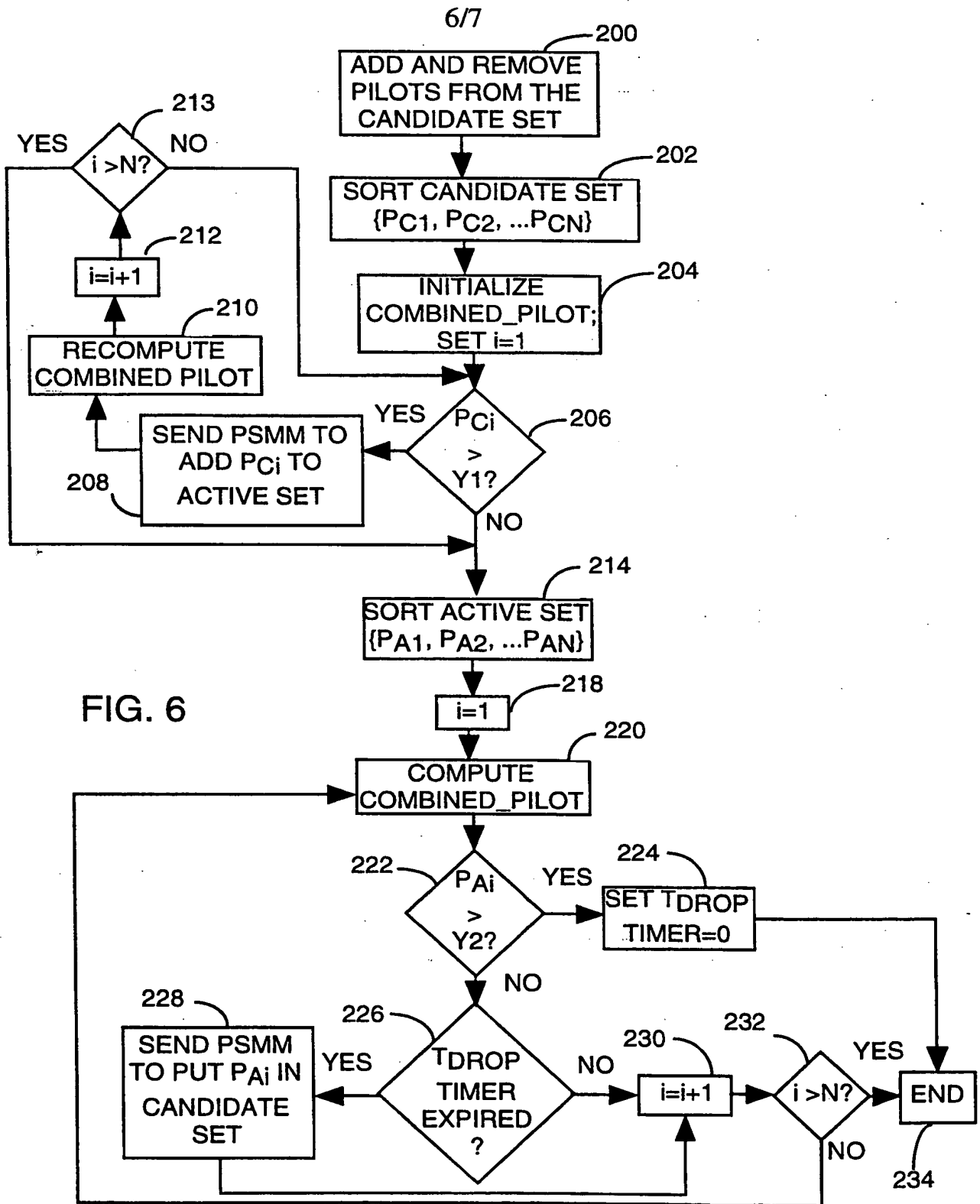


FIG. 5





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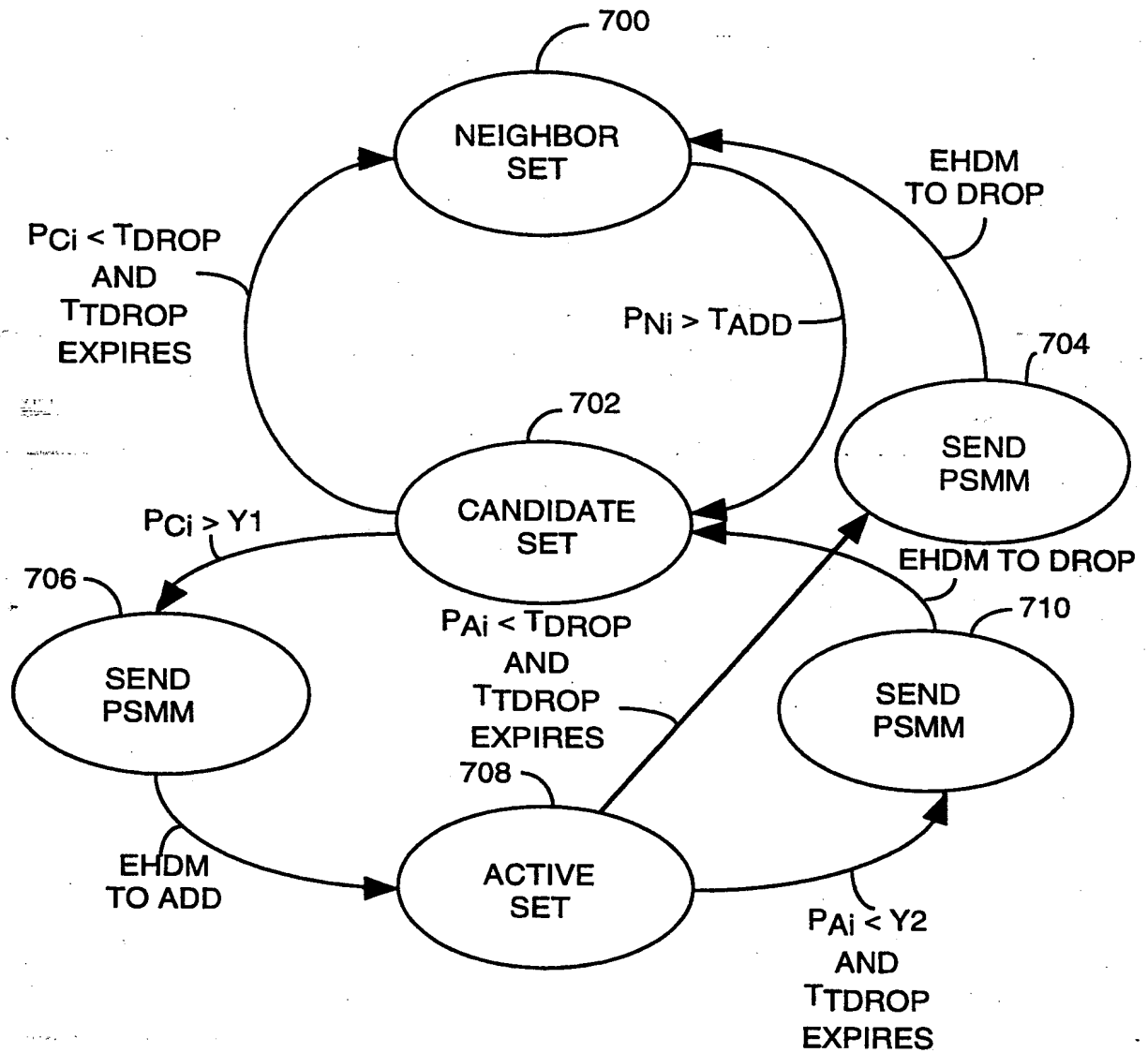


FIG. 7

# INTERNATIONAL SEARCH REPORT

International . . . . . Location No  
PC 98/14754

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 H04Q7/38 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No.         |
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

15 December 1998

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International Application No  
P S 98/14754

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